Research achievements

My recent research aims at a deeper understanding of AdS/CFT correspondence. AdS/CFT correspondence is one of the important topics in string theory up to now in this century. It claims the existence of a mysterious relation between quantum theory of gravity and gauge theory. Based on it, many researches has been done the analyses of gauge theory in terms of a (semi-)classical approximation of a theory of gravity. However, it is more non-trivial and important that there is a possibility to describe quantum theory of gravity in terms of gauge theory. It is expected that, by clarifying which gauge theory can possibly describe a quantum theory of gravity, one may gain deep insights into the structure of quantum theory of gravity.

In paper [10][1], I studied a three-dimensional gauge theory, so-called ABJM theory, with Prof. Soo-Jong Rey and Prof. Satoshi Yamaguchi, and investigated an expected relation to a gravity theory. This research was done at the early stage of study on ABJM theory, and our result has been cited until now since it discusses the relation between the Wilson loops and the string worldsheets, which is a fundamental relation in AdS/CFT correspondence.

In paper [7], I studied the large N limit of ABJM theory. The large N limit is a limit in which the properties of gauge theories become simplified, so that it has been studied to try to relate string theory and gauge theories, even before AdS/CFT correspondence. This paper is one of the earliest papers which discussed the behavior of the Wilson loops in the strong coupling regime. Such a large N analysis can be applied to more general three-dimensional gauge theories, in addition to ABJM theory. My recent papers showed such a systematic analysis, investigating the relation between gauge theories and corresponding theories of gravity.

ABJM theory is indeed a beautiful example of AdS/CFT correspondence. However, it might not be enough to focus on ABJM theory for understanding the correspondence. Rather, it would be helpful to study some family of gauge theories for which dual gravity theories would be absent, for highlighting the basic principle of the correspondence. I have been investigating various gauge theories recently based on this idea, and I hope that my systematic research would gain insights on the correspondence.

I studied "tachyon condensation" at the beginning of this century. It is known that string theory, at the time of birth, suffered from many pathologies, one of them being the presence of tachyons. This problem cannot be completely solved even after the introduction of supersymmetry. There has been a scenario of the resolution since the beginning of string theory: tachyons appearing in string theory would be like the Higgs particles in particle physics, and the correct vacuum would be realized when the tachyons get non-zero vacuum expectation values ("condenses"). It was clarified in the late 90s that the scenario is indeed realized in some situations in string theory. In these examples, it was the tachyon in open string theory that was discussed.

Paper [27] discussed tachyons appearing in a closed string theory, and proposed a conjecture on the properties of the vacuum state which is expected to be realized after tachyon condensation. This paper was awarded Particle Physics Medal: Young Scientist Award in Theoretical Particle Physics in 2008. The closed string tachyon condensation attracted attentions from many researchers since 2001. I think I did contribute to the investigations of the topic.

In the research of string theory, people often needs to know the properties of the theory when the coupling constant is large. Also, it is often happens that the description of a string as an object moving in a classical geometry is not adequate since the curvature is very high, for example. In such situations, we cannot rely on the existing perturbative formulation of string theory, and we need a better formulation. In the late 90s, such an idea was shared among researchers, resulting in several proposals for new formulations. One of them is so-called IIB matrix model which was proposed by a Japanese group.

In paper [33], Prof. Asato Tsuchiya, one of the founder of IIB matrix model, and I investigated the model, and found an important property of the fine structure of the space-time which is expected to be described by the model. This result has been one of the key properties in the further researches on IIB matrix model.

In addition, I studied various issues in string theory. An example is on the thermodynamics of black holes. It is expected that string theory includes many topics in physics, if not all, so the importance of researches from various points of view will become more and more important in the future.

[1] For the numbers of papers, refer to the list of publications.